National Aeronautics and Space Administration

Turbulence Measurements in Rectangular Jets with Aft Deck

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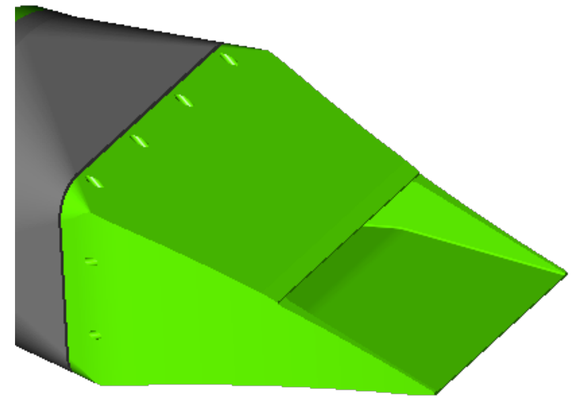
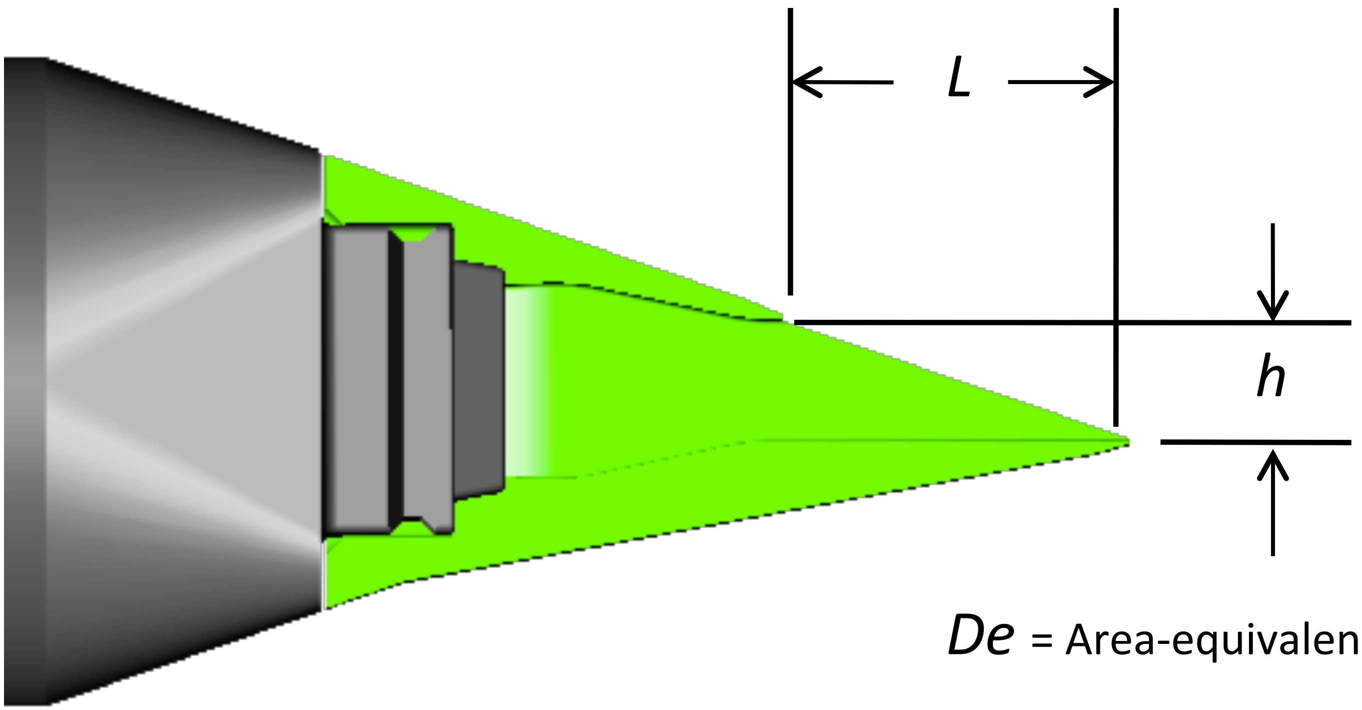
Nomenclature — 1/2

- Aft Deck as extension of nozzle
  - Length *L*
  - Aspect ratio *AR*
  - Slot height *h*

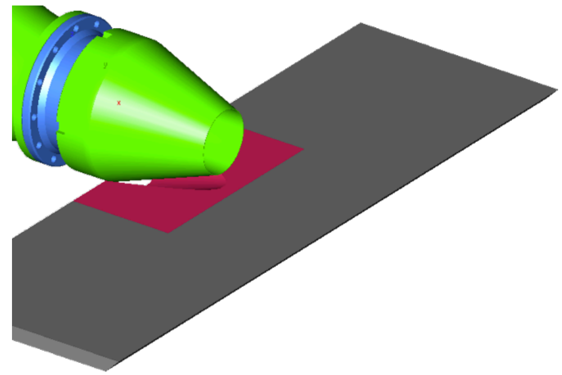


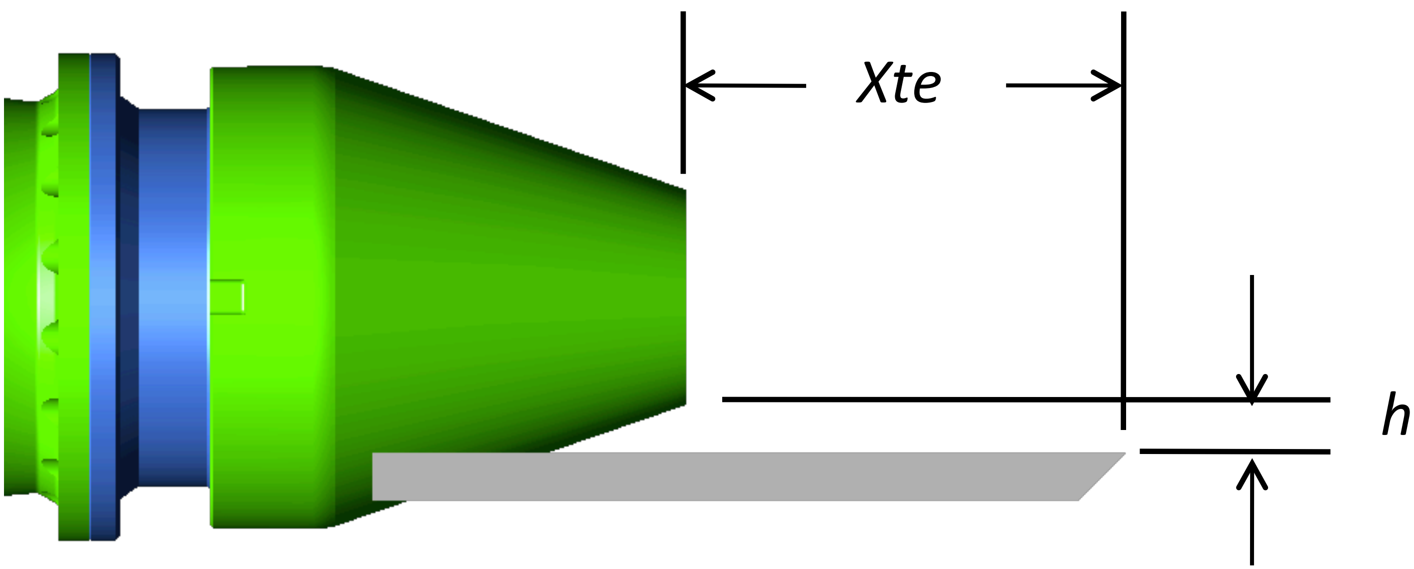


De = Area-equivalent Diameter

Nomenclature — 2/2

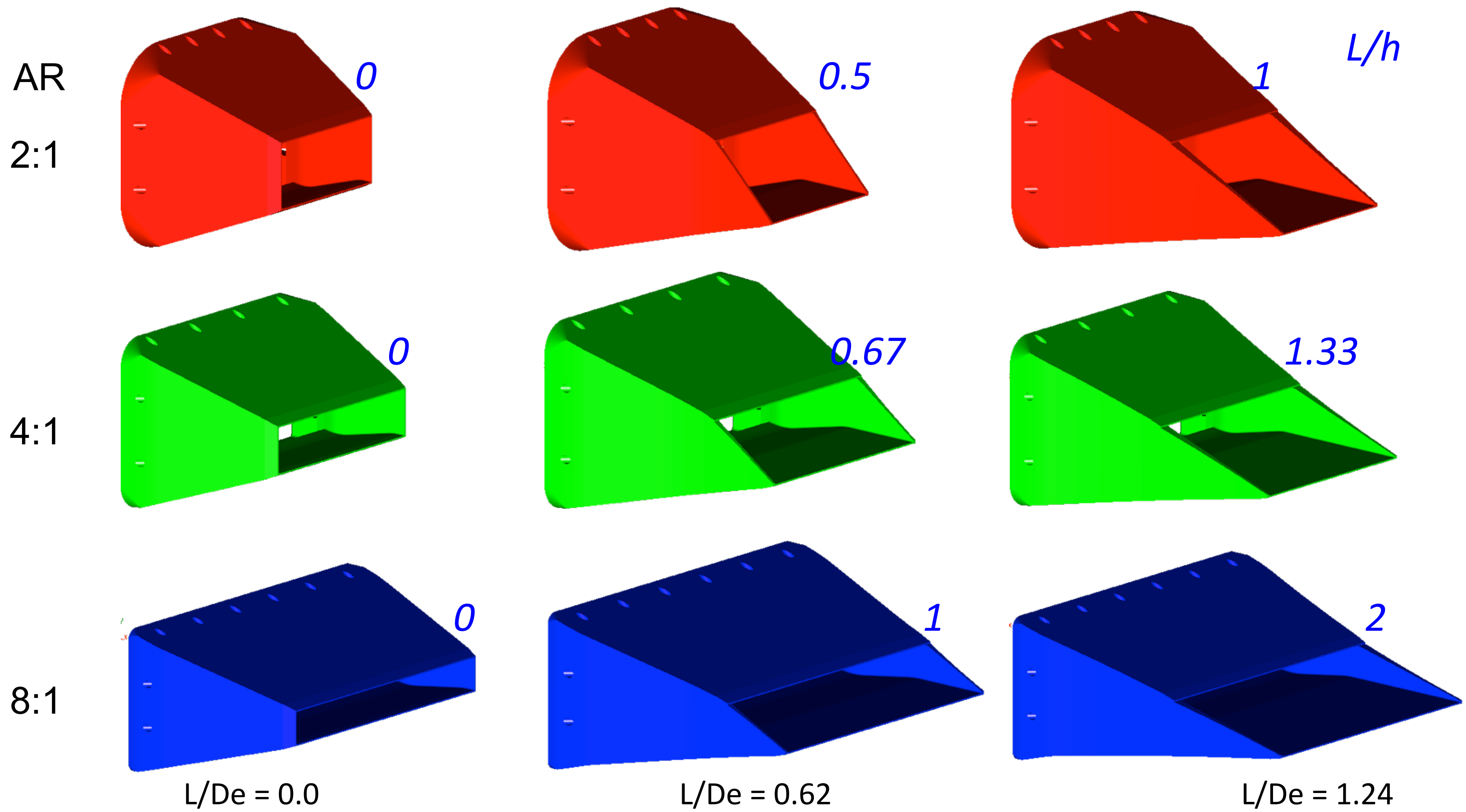
- Aft Deck standing off from Nozzle
  - Trailing Edge Length, *Xte*
  - Standoff from lipline, *h*





Nozzle geometries

- Nozzles designed to minimize velocity distortion at exit (Frate & Bridges AIAA 2011-0975)
- Parametric variation in aspect ratio (AR) and bevel length (L/De)

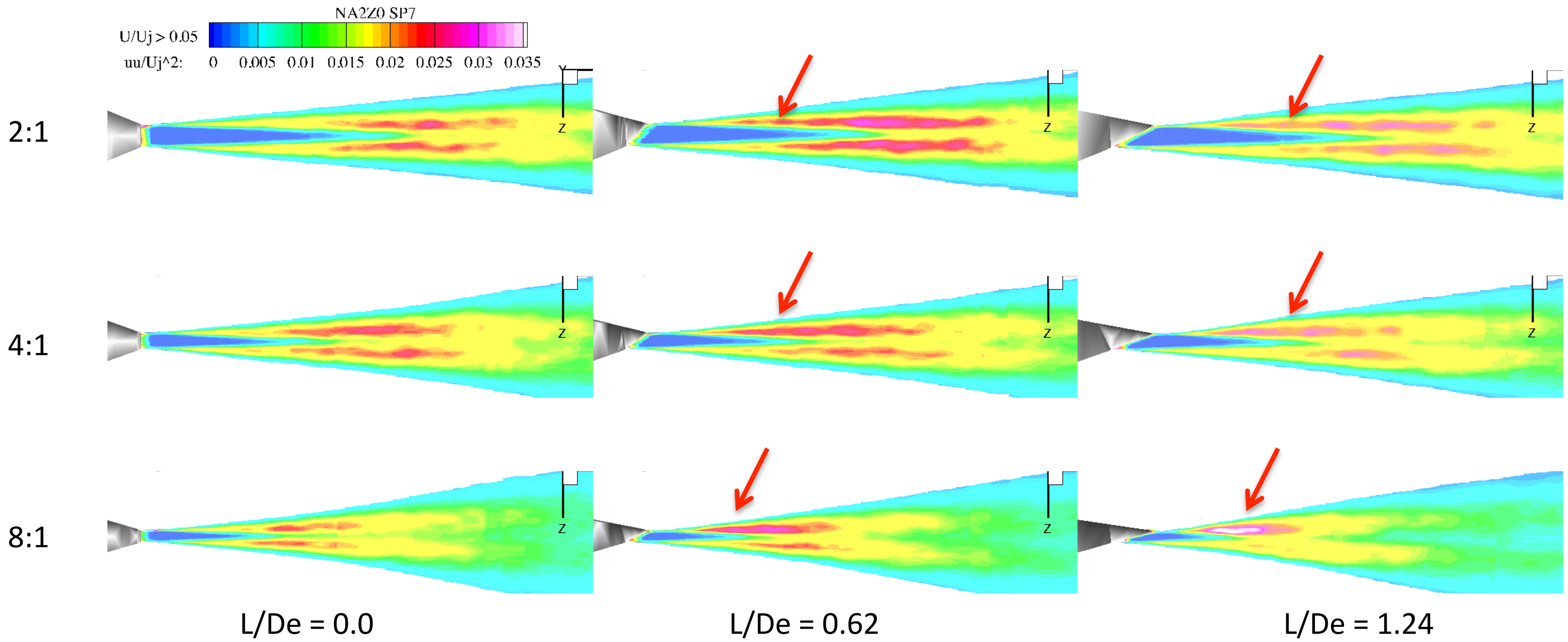


Conclusions from PIV studies of Rectangular Jets *Without* Aft Deck

- Potential core relative to nozzle area shrinks with increasing aspect ratio
  - Scales with slot height.
- 10% variation in peak turbulence intensities of rectangular jets
  - Increasing aspect ratio lengthens peak region, lowers peak.
  - TKE = $(u^2+v^2+w^2)/2$ is well approximated by u^2.
- Increased coherence (longer lengthscales) in minor axis plane
  - Jet likes to flap

Rectangular Nozzles with Aft Deck

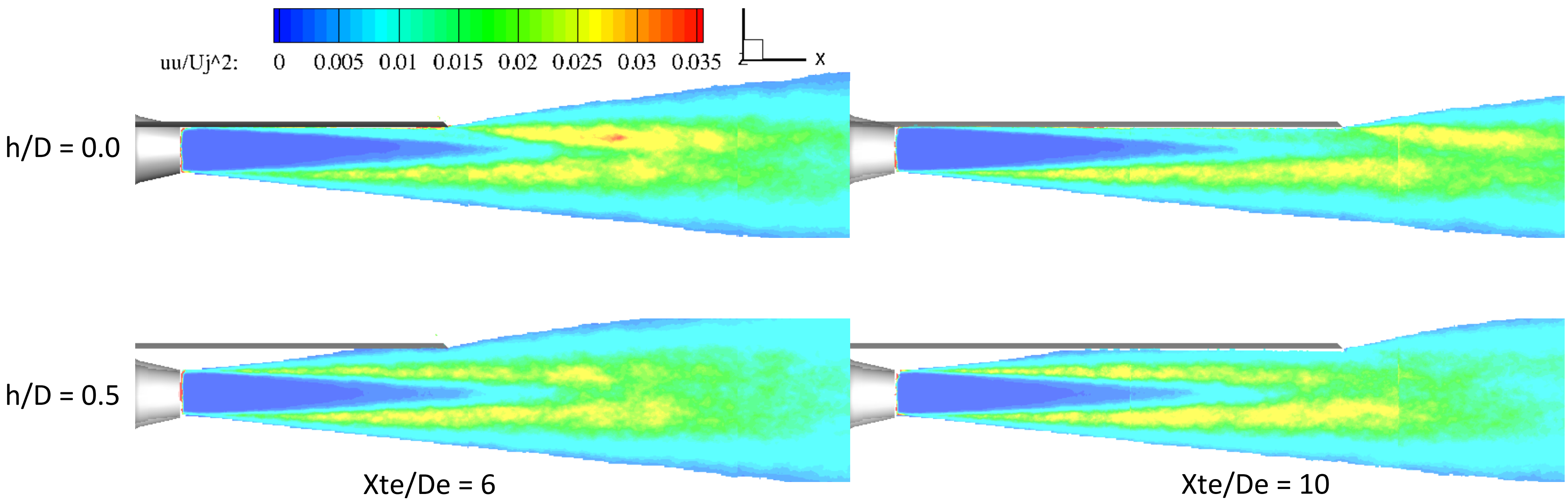
- Constant Deck Standoff = 0
- Vary Trailing Edge length, L
- Vary nozzle aspect ratio



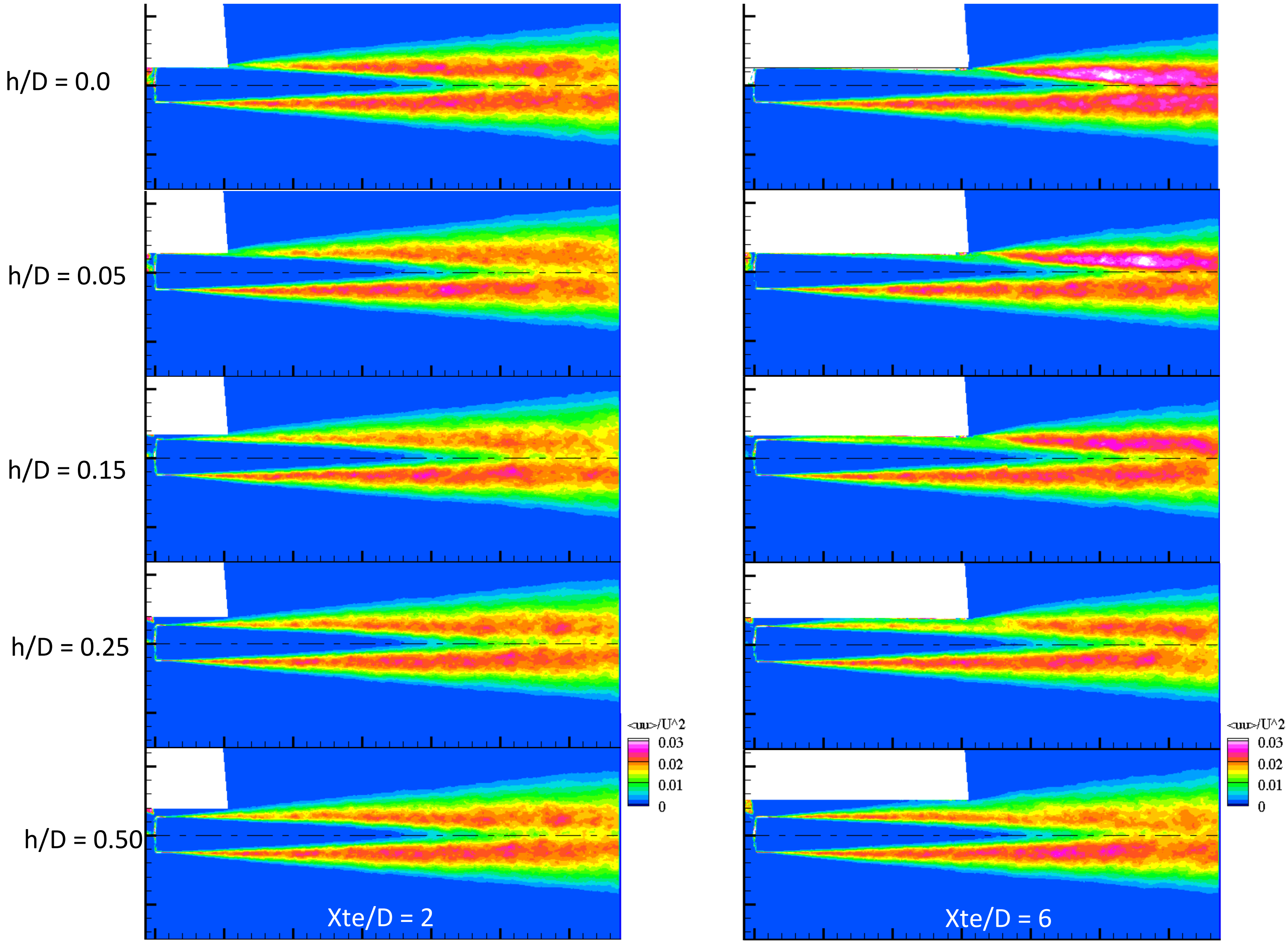
Round Nozzles with Aft Deck

(Fixed Wing's Jet Surface Interaction Test)

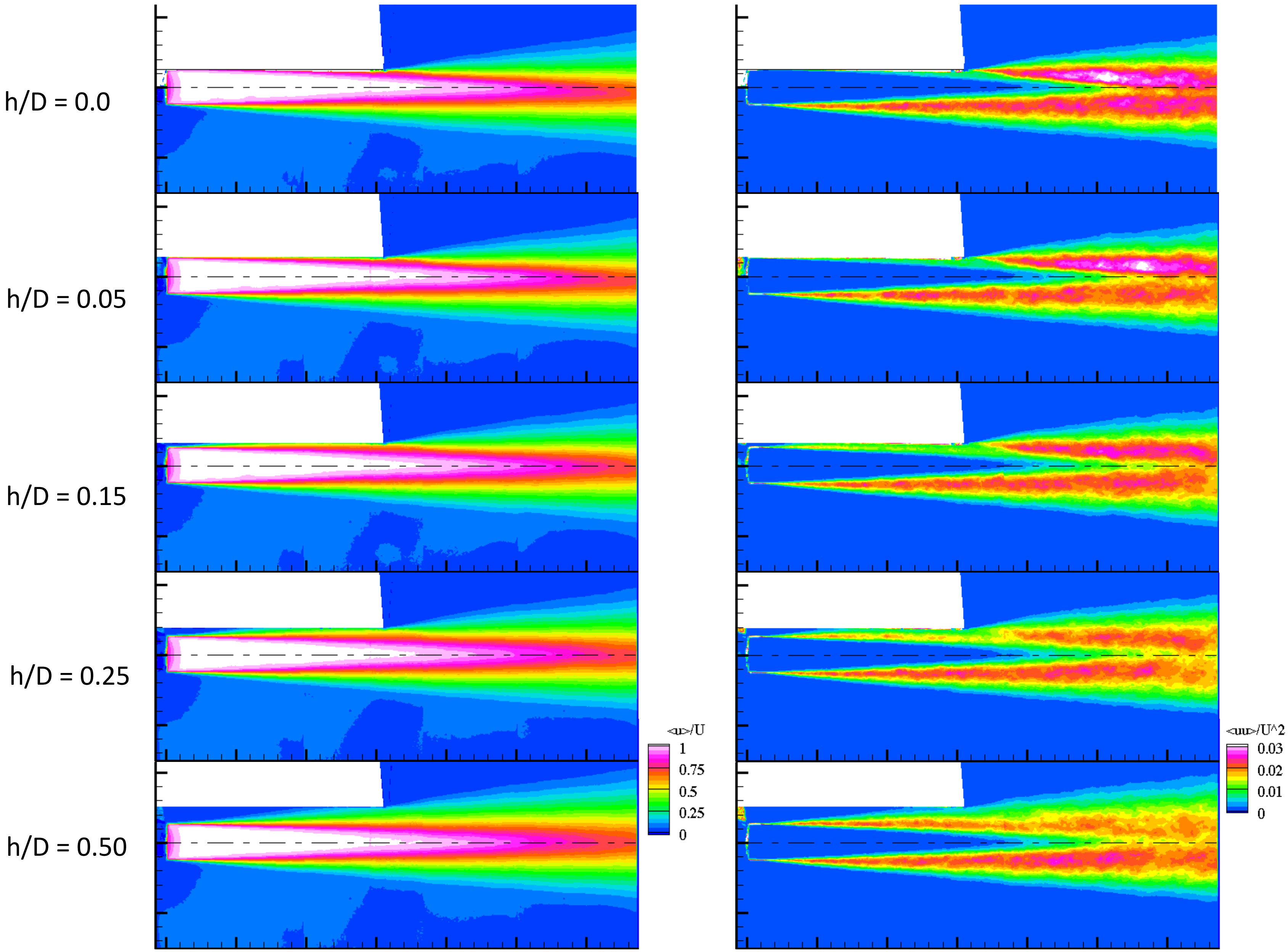
- Vary Deck Standoff from lipline, h/D
- Vary Trailing edge length, Xte
- Constant nozzle geometry (round)



Dependence of second shear layer on plate length

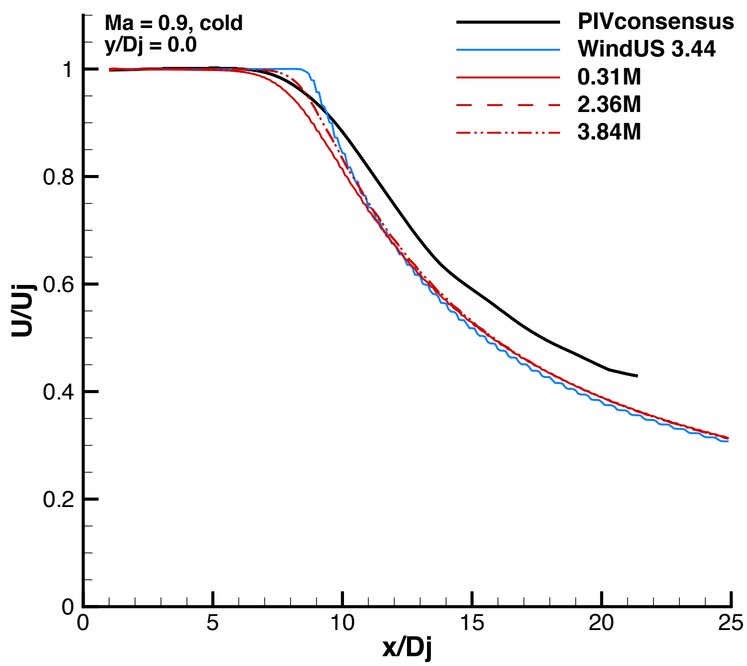


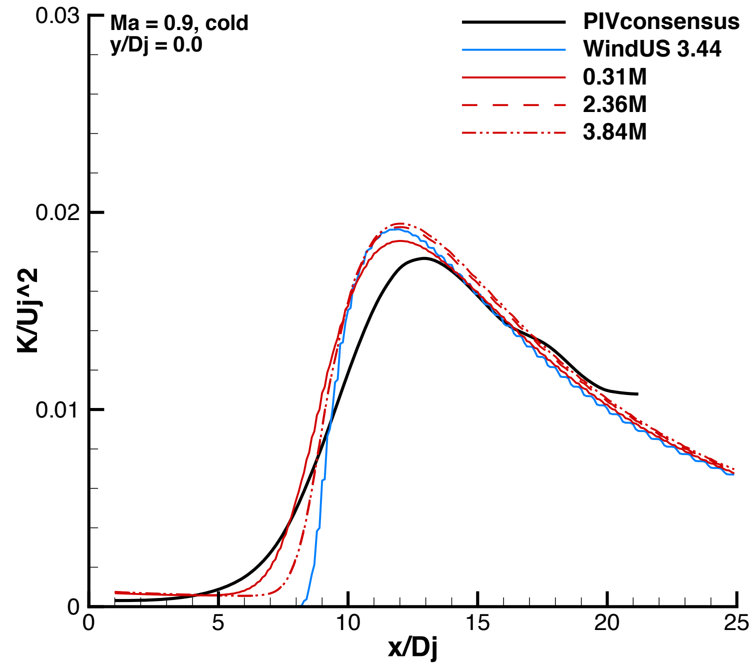
Correlation of plume vectoring and turbulence



Validating RANS

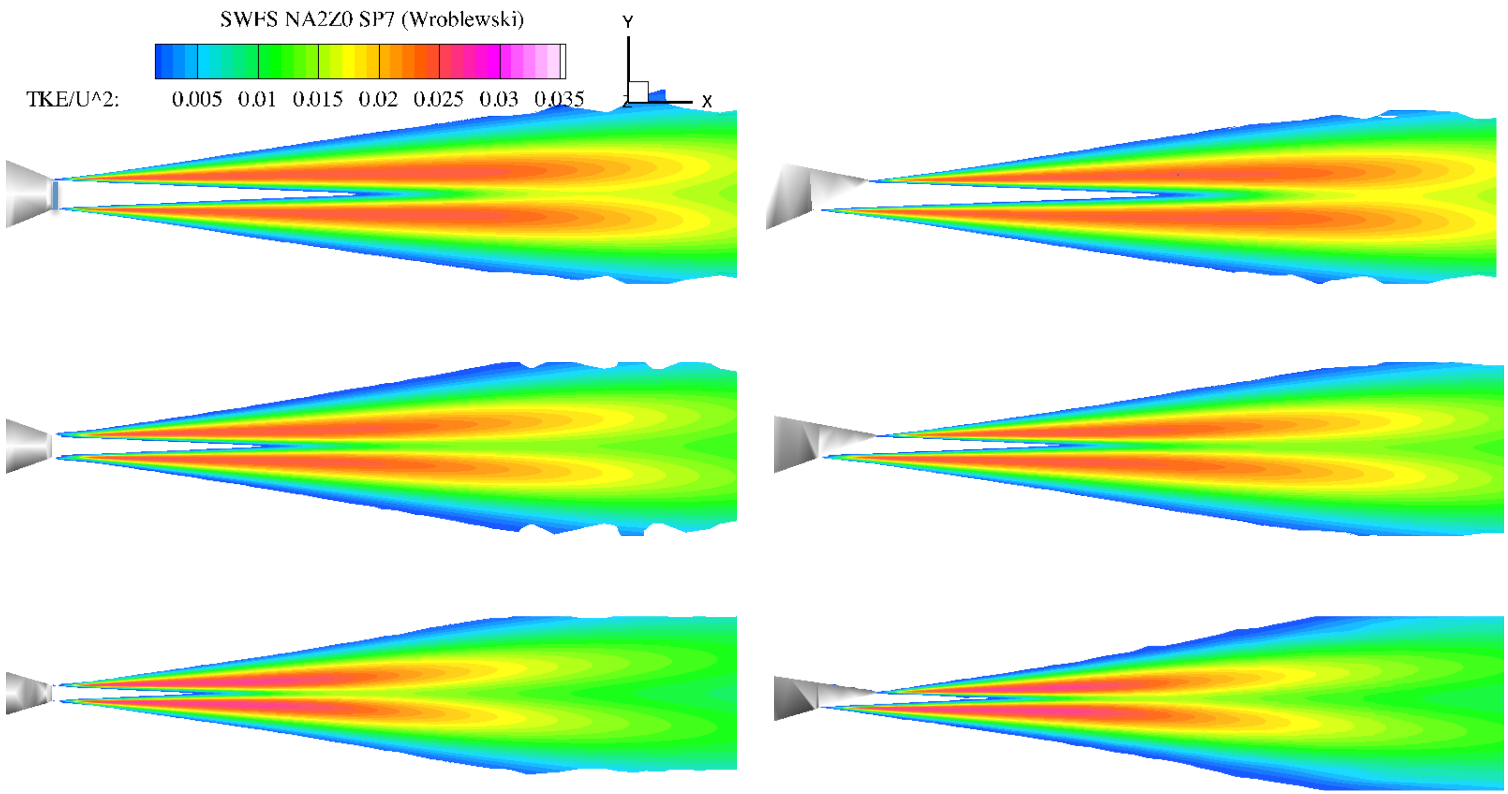
- Primarily using *WindUS* and Daussalt Systems' *SolidWorks Flow Solver*
- Using K-espsilon or SST Mentor turbulence models
- WindUS uses structured grid, SWFS uses unstructured grid with auto refinement.
- Previous experience with RANS on isolated jets favorable, especially for cold subsonic jets.
  - Peak TKE correct, within a jet diameter of proper location
  - Codes give comparable results, relatively insensitive to grid.





Rectangular Nozzles with Aft Deck

- RANS Predictions



2:1

4:1

8:1

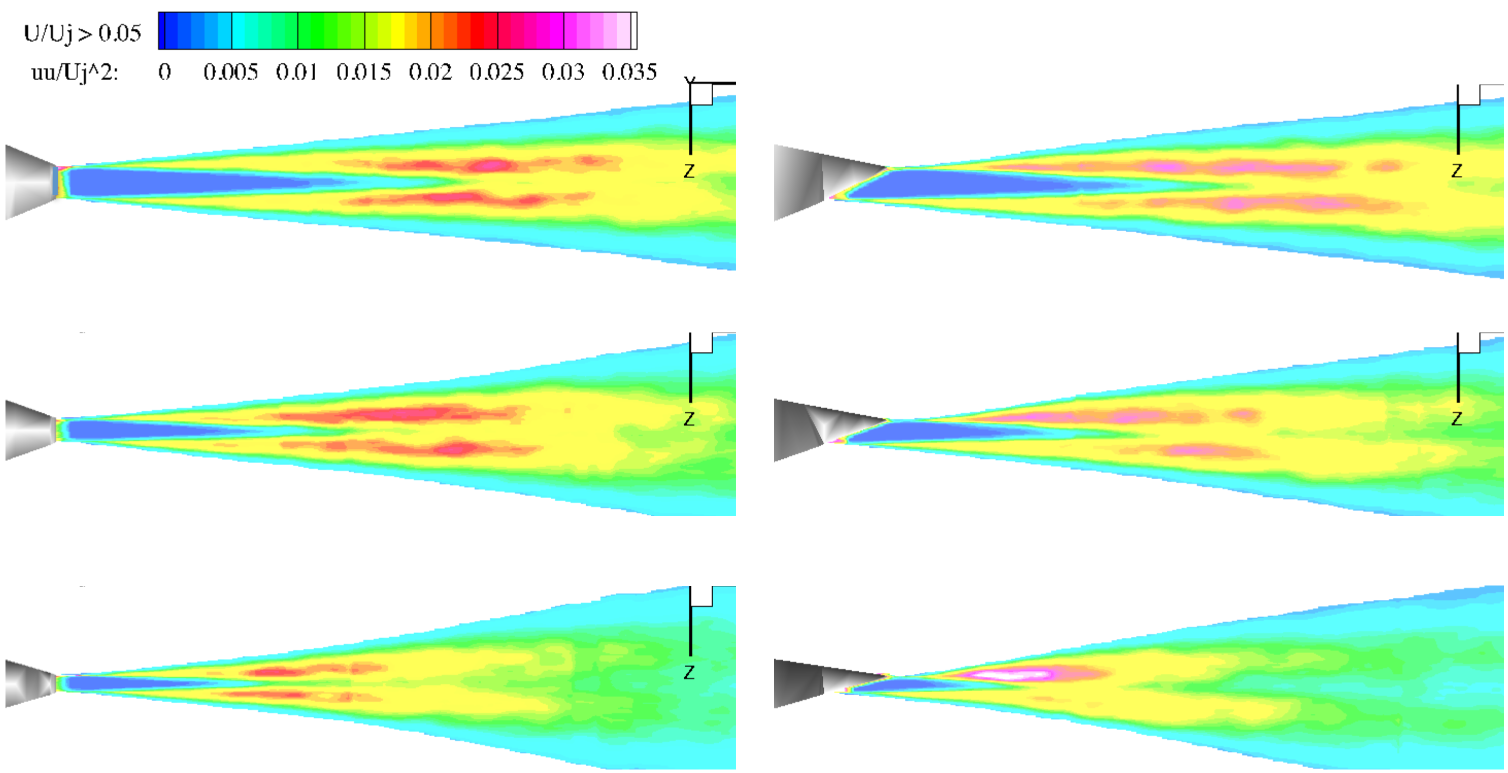
L/De = 0.0

L/De = 1.24

Marginal asymmetry!

Rectangular Nozzles with Aft Deck

- PIV measurements



2:1

4:1

8:1

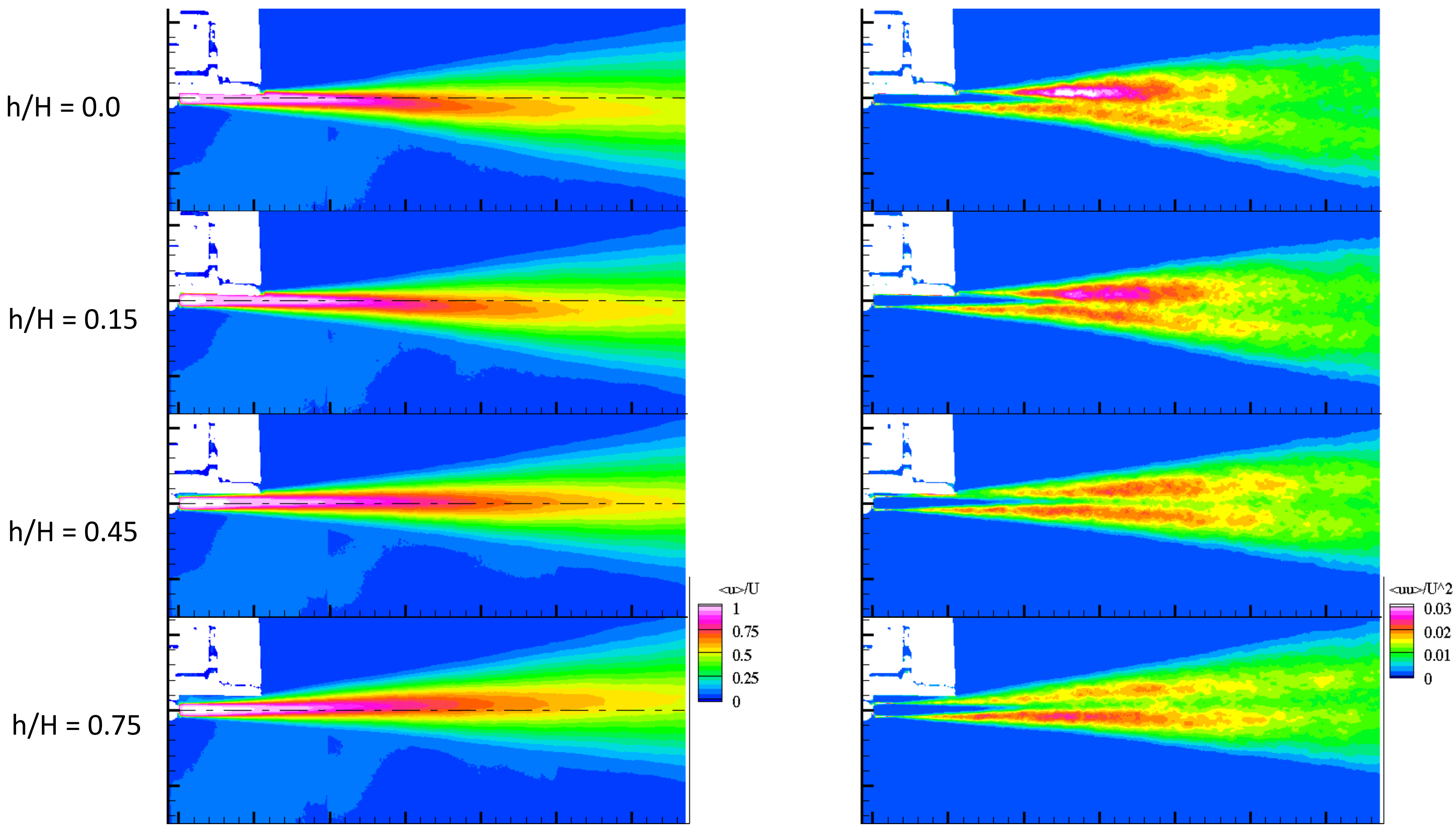
L/De = 0.0

L/De = 1.24

Significant asymmetry!

Rectangular Nozzles with Aft Deck with Standoff

Xte/D = 2

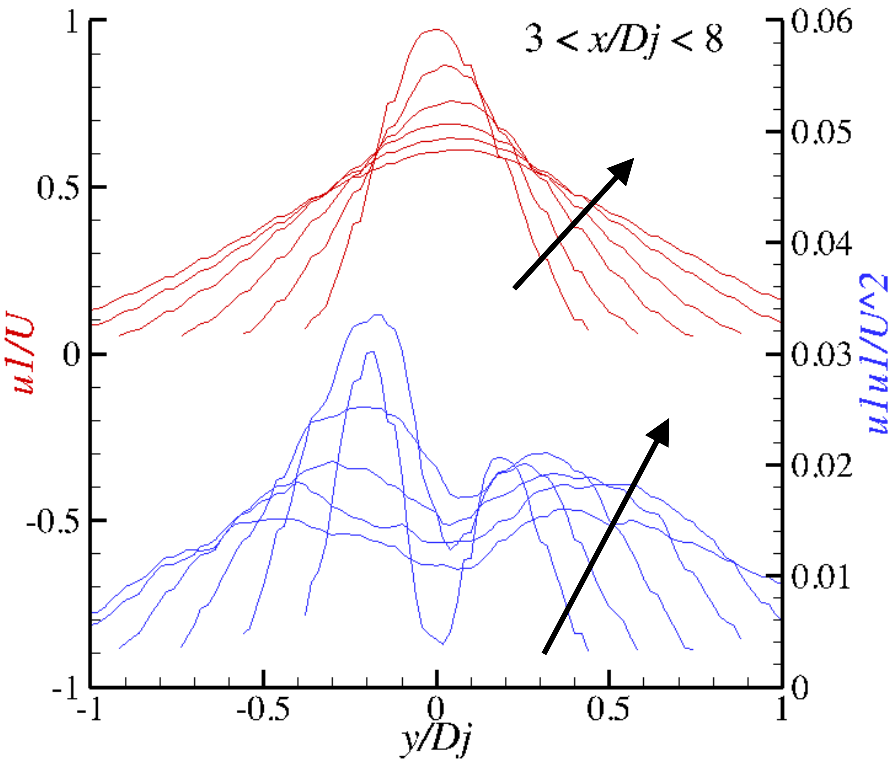


Plume Asymmetry Downstream of Aft Deck

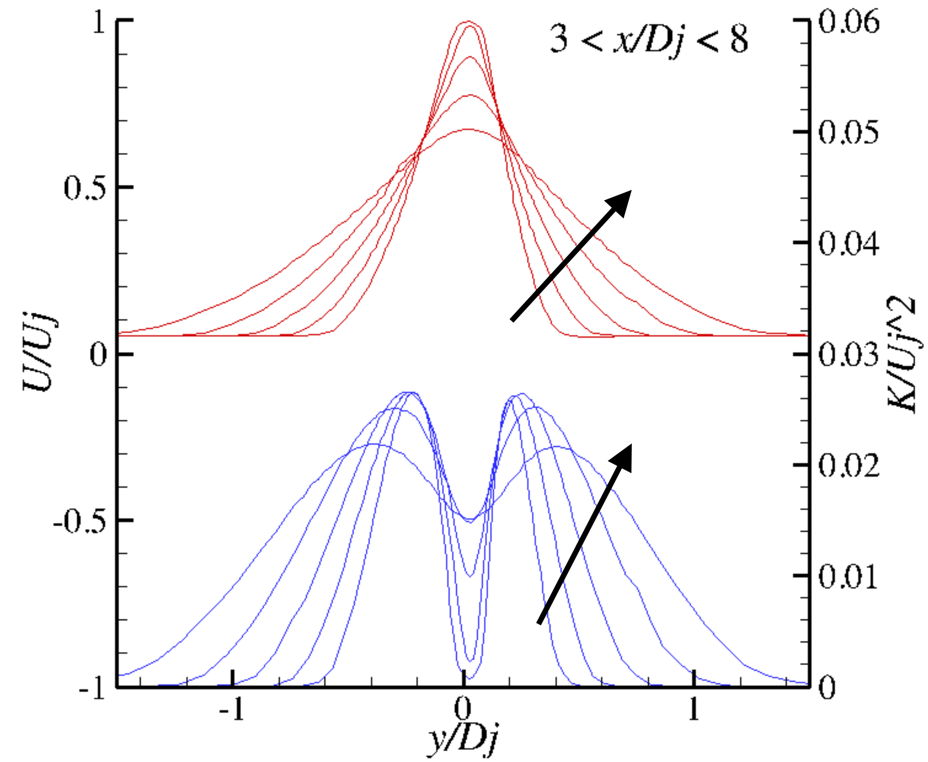
- 8:1 nozzle with *L* = 2.7*De*
- Cold, *Ma* = 0.9 flow

Mean axial velocity
Turbulent axial velocity

PIV



RANS CFD

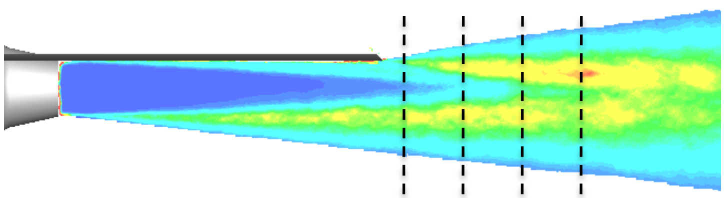


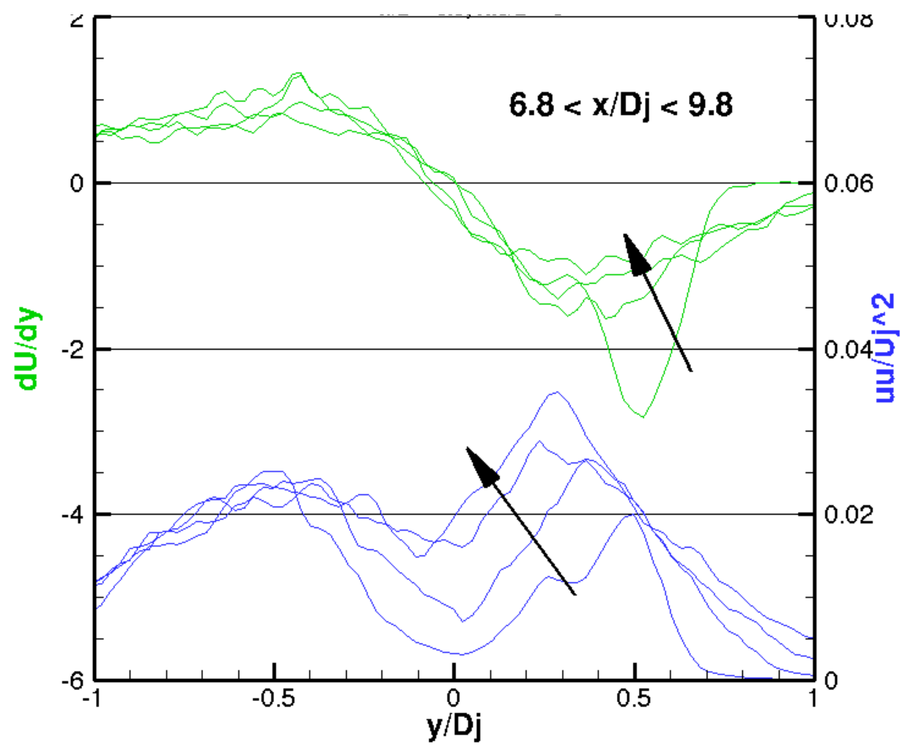
Source of Enhanced Turbulence?

Shear stress downstream of plate in round jet

- Radial profiles from shortly downstream of plate to where peak turbulence occurs.
- Shear stresses only slightly asymmetric. Enough?

Xte/Dj = 6, *h* = 0





Summary

- Rectangular jets studied as prototypical non-circular jet.
- Most turbulence statistics similar to round jets.
- Surface in close proximity to jet can produce high turbulence levels just downstream of surface trailing edge.
  - Demonstrated on rectangular and circular nozzles
  - Degree of amplification dependent upon many factors
  - Amplification reduced quickly as surface is removed from jet.
- RANS CFD does not seem to pick this up.
- Early in exploring cause of RANS failure to predict enhanced turbulence by aft deck.

TREC13 PIV Supplemental plan

- To capture what happens to the TKE between h/D = 0.0 and 0.5, we will repeat these two cases and two in between using the same Xte/D = 6 wall
- In addition, we will repeat this for shorter wall which may be of more interest in practice.
- Anticipating that the large AR nozzle is an accentuated version, we will test A8Z0 with a plate that matches the A8B2 bevel and then add standoff. We will also make this more extreme by adding wall length.
- Finally, at Mark Wernet's suggestion we will try transient acquisition, both moving the nozzle toward and away from the plate, to see exactly where the behavior changes.
- We will only limit ourselves to setpoint 7, no freejet for expediency
- We will only limit ourselves to the first 25" of flow.
- We will only measure single nozzle configurations, not twin.

Planned TREC13 PIV Surface Supplement Test Matrix

Nozzle	Spacing	Clocking	Surface Xte (inches)	Surface h (Inches)	Setpoints	Mf
TCON	NA (Z9)	150	12	0	70	0.05
TCON	NA (Z9)	150	12	0.2	70	0.05
TCON	NA (Z9)	150	12	0.5	70	0.05
TCON	NA (Z9)	150	12	1	70	0.05
TCON	NA (Z9)	150	4	0	70	0.05
TCON	NA (Z9)	150	4	0.1	70	0.05
TCON	NA (Z9)	150	4	0.3	70	0.05
TCON	NA (Z9)	150	4	0.5	70	0.05
A8Z0	NA (Z9)	150	4	0	70	0.05
A8Z0	NA (Z9)	150	4	0.1	70	0.05
A8Z0	NA (Z9)	150	4	0.3	70	0.05
A8Z0	NA (Z9)	150	4	0.5	70	0.05
A8Z0	NA (Z9)	150	2.7	0	70	0.05
A8Z0	NA (Z9)	150	2.7	0.1	70	0.05
A8Z0	NA (Z9)	150	2.7	0.3	70	0.05
A8Z0	NA (Z9)	150	2.7	0.5	70	0.05